

## REPORT DOCUMENTATION PAGE

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U.S. Army Research, Development and Engineering Command

**A Bipolar Current Actuated Gate  
Driver for JFET Based  
Bidirectional Scalable Solid-  
State Circuit Breakers**



***TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.***

**Inventor: Mr. Damian Urciuoli**

ARL 10-14

APPROVED FOR PUBLIC RELEASE

February 16, 2011

## Technology Overview

The invention can improve high speed bi-directional fault protection in a broad range of power conversion and distribution systems such as hybrid vehicle drives and renewable energy systems.

This gate driver enables bidirectional over-current protection to prevent system damage and destructive failure. Key features/benefits include:

- Controls normally-ON scalable bidirectional solid-state circuit breakers (BDSSCBs)
- Fast acting: actuates in approximately 2  $\mu$ s
- Provides over-current protection, automatically compensating for temperature changes
- Responds to external sensor triggering, in addition to internal triggering
- Ultra low power consumption in the BDSSCB ON-state
- Has been demonstrated using very normally-ON 1.2-kV, 10-A silicon carbide (SiC)JFETs
- A robust addition to a battery pack providing protection during charge, discharge, and servicing.

## Mechanical Fault Protection

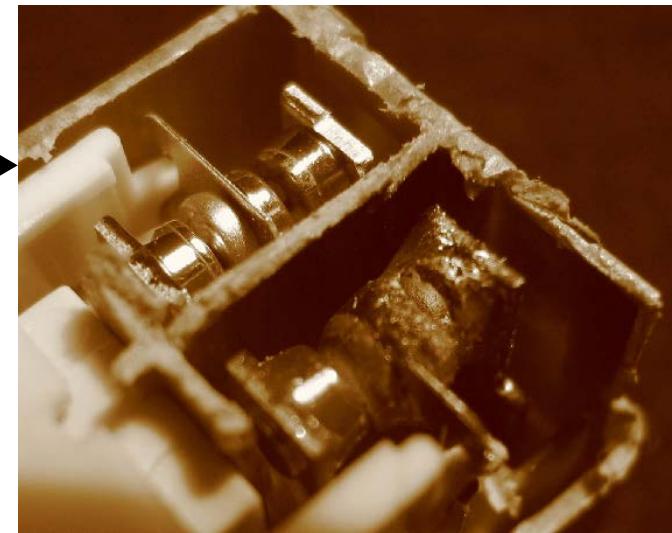
- Actuation times: 10 to 100 of milliseconds
- Low number of high energy fault events
- Suffer contact degradation
- + Low conduction and switching losses (heat)
- + Provides bi-directional isolation

**VS.**

## Bi-directional solid-state fault protection

- + Actuation times with voltage suppression: 10 to 100 of microseconds, **10<sup>3</sup> faster**
- + Endures large number of high energy fault events
- + Ultra low degradation = high reliability and longevity
  - Conduction and switching losses (clearly manageable)
- + Controls bi-directional fault isolation

## Technology Differentiation



Pros: +
Cons: -

## Technology Advantages

### Key advantages of this fault protection vs. generic solid-state

- Solid-state bidirectional protection for both DC and AC operation
- Normally-ON fault tolerant protection with no voltage to hold the ON-state
- SiC JFET is manufacturable and mature (inexpensive in production)
- Scalable design
- Very low driver cost
- Temperature compensated over-current protection

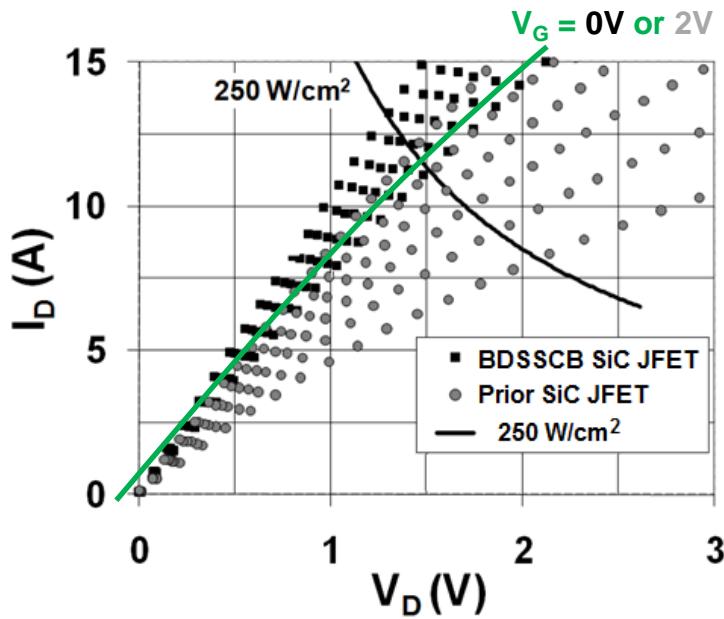
## Technology Proof of Concept

Normally-ON is the desired default state:

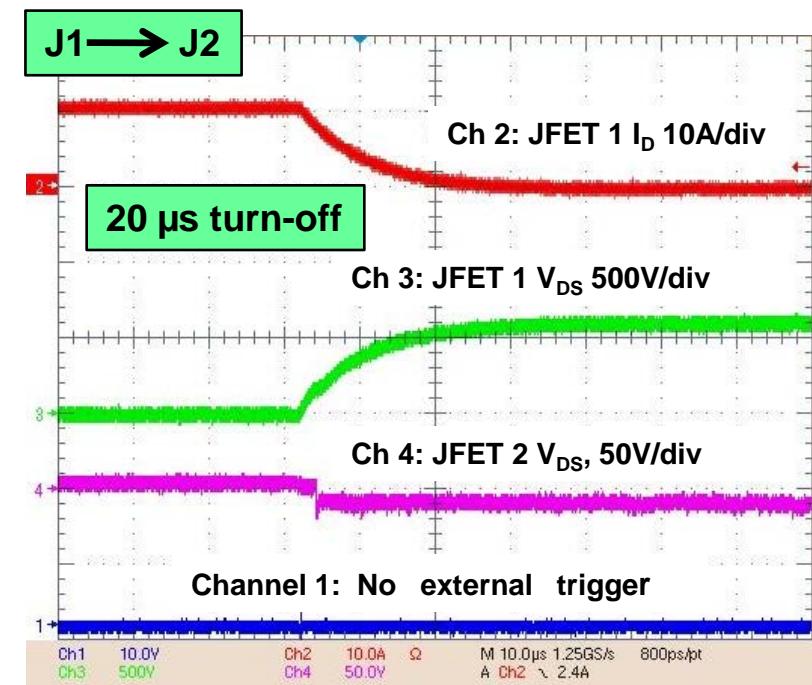
The (Junction Field Effect Transistor) JFET is a **normally-ON\***, **bi-directionally conducting**, **uni-directionally voltage blocking** semiconductor device. It provides more fault tolerant fault protection; high speed actuation (microsecond vs. millisecond); allows temperature compensated over-current protection; and improved reliability.

\* Not all JFETs are normally-ON

Positive gate bias can improve conduction . . . or . . . **JFETs can be designed for zero-volt bias (very normally-ON)**



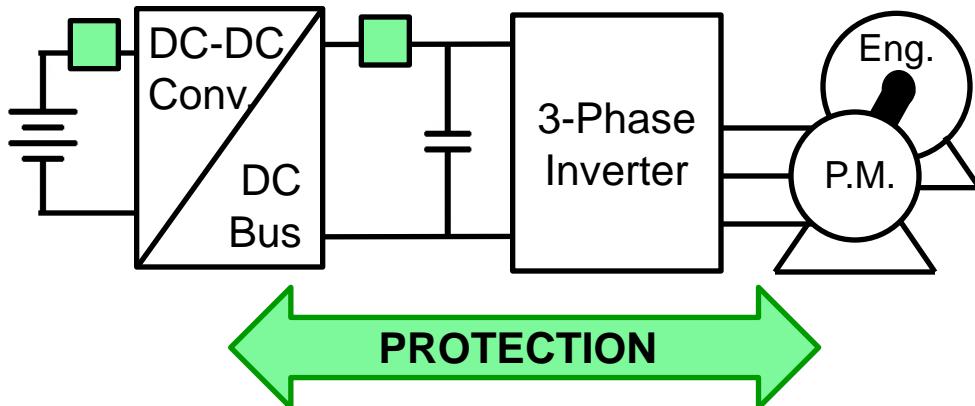
600 V, 10 A turn-off waveforms (10  $\mu$ s per division)



## Military Applications

### BDSSCB is especially applicable to:

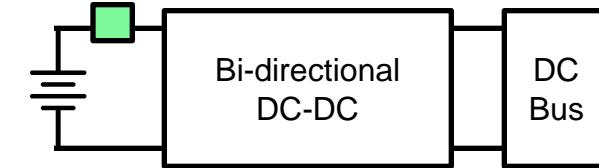
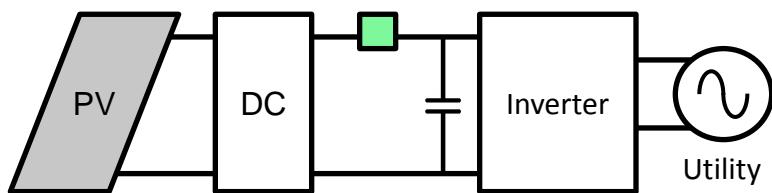
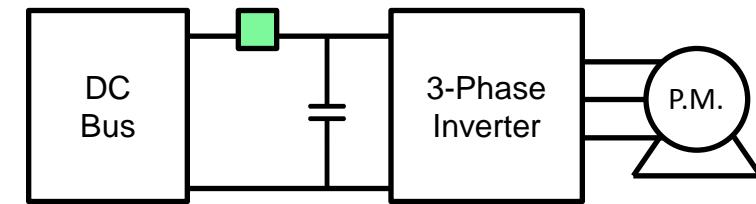
- Hybrid electric vehicle power systems
- Electrical energy storage systems having bidirectional power flow
- Military tactical and combat ground vehicles and aircraft where fault protection is critical for mobility and survivability.



## Commercial Applications

### BDSSCB applications: DC or AC

- Hybrid electric vehicle systems
- Grid-tie renewable energy inverter systems
- Bidirectional DC-DC converters
- Charge and discharge of energy storage systems
- Regenerative power (brakes, elevators, etc.)



## Technology Agreements

A patent license and CRADA is sought.

The current technology is TRL-5 and will benefit from a collaboration between the inventor team and the commercialization partner in order to speed the development to the market. This would most readily be done through a patent license agreement and CRADA.

A patent application has been filed.